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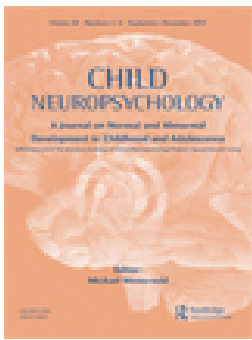
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## Aggressive behavior during toddlerhood: Interrelated effects of prenatal risk factors, negative affect, and cognition

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### ABSTRACT

Prenatal risk, temperamental negative affect, and specific cognitive abilities have all individually been identified as predictors of behavior problems during early childhood, but less is known about their interplay in relation to aggression during toddlerhood. This study examined the main and interaction effects of prenatal risk, negative affect, inhibitory control, attention, and vocabulary in the prediction of aggression in 150 children (75 boys). During pregnancy, a cumulative risk index was calculated based on the presence of 10 well-established maternal risk factors, such as prenatal substance use, maternal psychiatric disorder, and financial problems. Negative affect was measured at 6 and 20 months using maternal report. Child cognition was examined at 30 months using laboratory tasks for inhibitory control and attention, and a questionnaire was administered to assess vocabulary. In addition, mothers reported on their children's aggressive behavior at 30 months. Higher prenatal risk and negative affect at 20 months and, to a lesser extent, at 6 months were related to more aggression at 30 months. Poorer inhibitory control and, to a lesser extent, vocabulary at 30 months also predicted higher levels of aggressive behavior. Two-way interaction effects were found for cumulative risk and inhibitory control, negative affect (at 20 months) and inhibitory control, and negative affect (at 6 months) and vocabulary: aggressive behavior was most pronounced when combinations of high prenatal risk, high negative affect, and poor cognition were present. These results suggest that the impact of prenatal risk and child temperament depends in part on child's cognitive development during toddlerhood.

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Although a certain degree of aggressive behavior is considered normal during infancy and toddlerhood (Tremblay & Nagin, 2005), persistent and high levels of aggression during early childhood have been associated with negative outcomes later in life, such as delinquency, school dropout and internalizing and externalizing problems (Broidy et al., 2003; Campbell et al., 2006; Masten et al., 2005; Mesman et al., 2001). Prenatal risk, temperamental negative affect and aspects of early cognitive development have all individually been identified as predictors of behavior problems during early childhood

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(Latimer et al., 2012; Sanson et al., 2004; Schoemaker et al., 2013). To date, studies examining their relative predictive power and their interplay in relation to aggression, especially during toddlerhood, are lacking.

### *Risk in relation to aggressive behavior*

Previous research has demonstrated the impact of several pre- and perinatal risk factors on children's behavioral development, particularly the development of aggressive behavior (Carneiro et al., 2016; LaPrairie et al., 2011; Latimer et al., 2012). Prenatal substance use, low maternal education, maternal psychiatric disorder, young maternal age, and being a single parent are some examples of factors that have been associated with the development of aggressive behavior (Bradley & Corwyn, 2002; Côté et al., 2007; Huijbregts, Séguin, et al., 2008; Luoma et al., 2004; Velders et al., 2011). Given the frequent co-occurrence of these risk factors (Carneiro et al., 2016), a common approach to examine environmental risk is to use the cumulative risk model, which emphasizes the number of risk factors instead of the intensity or nature of specific risk factors (Evans et al., 2013; Sameroff et al., 2004). It has been shown that a cumulative risk model is more parsimonious, more ecologically relevant, and statistically more powerful in predicting behavioral development compared to specific patterns of individual risk factors (Evans et al., 2013; Flouri & Kallis, 2007; Sameroff et al., 2004). Studies using the cumulative risk approach have shown that a higher number of risk factors are clearly related to higher levels of aggressive behavior during early childhood (Bennett et al., 2013; Gassman-Pines & Yoshikawa, 2006; Trentacosta et al., 2008; Wallander et al., 2019).

The risk-aggression relation may, in part, be explained by the heritability of psychopathology (Lahey et al., 2011). In addition, repeated or prolonged stress associated with risk may cause lasting alterations in the regulatory systems (Juster et al., 2011; Sterling, 2012), such as changes in stress hormone levels, and structural, functional and neurochemical changes in brain regions involved in emotional processing, including the hippocampus, amygdala, and prefrontal cortex (Ganzel et al., 2010; McEwen, 2000). These lasting physiological alterations could lead to psychopathology, such as aggressive behavior (Juster et al., 2011).

### *Temperamental negative affect in relation to aggressive behavior*

Temperament is an important precursor of children's social development (Sanson et al., 2004), and has been defined as the individual differences in a set of biologically based traits concerning reactivity and regulation (McCrae et al., 2000; Rothbart & Bates, 2006). Although the definition might suggest that temperament consists of a set of relatively fixed traits, evidence for the stability of temperament is lacking, with only modest-to-moderate associations between different measurements of temperament throughout early childhood (Carranza et al., 2013; Ferguson, 2010; Kopala-Sibley et al., 2018). The limited stability throughout development, in turn, points to the existence of both genetic and environmental influences on temperament (Emde et al., 2001; Nigg, 2006). One of the key reactive dimensions of temperament is negative affect, which concerns the tendency to experience and express negative emotions, such as anger, frustration, fear, and sadness (Rothbart & Bates, 2006; Sanson & Rothbart, 1995). Higher negative affect,

as well as higher levels of specific aspects of negative affect, including irritability and fear, has frequently been associated with externalizing behavior problems during early childhood (DeLisi & Vaughn, 2014; Muris & Ollendick, 2005; De Pauw & Mervielde, 2010; Sanson et al., 2004).

In addition to the direct contribution of temperament to externalizing behavior problems, a difficult temperament, when combined with environmental risk, also constitutes a vulnerability for psychopathology (Monroe & Simons, 1991; Nigg, 2006). According to the diathesis-stress model, high negative affect may increase the risk for psychopathology in case of high environmental risk, whereas low negative affect will have a protective effect. Several studies have provided evidence supporting the diathesis-stress model for externalizing behavior, mainly focusing on interactions between temperament and parenting behavior as “environmental risk factor” (Slagt et al., 2016). High parental hostility or discipline and low parental sensitivity were related to higher levels of externalizing behavior, but only in children with a difficult temperament (Bradley & Corwyn, 2008; Morris et al., 2002; Van Zeijl et al., 2007). With regard to a cumulative risk index, stronger associations between risk and problems with emotion regulation during preschool were found for children high in negative affect during toddlerhood, which in turn predicted social behavior at the age of five (Chang et al., 2012). Other studies did not find a moderating effect of negative affect on the relation between cumulative risk and child social outcomes during early childhood (Lengua, 2002; Northerner et al., 2016). There may be different causes for inconsistencies in results from different studies, one of these being the exact choice of the outcome measures, such as social competence, externalizing behavior problems, or a combination of internalizing and externalizing behavior problems. Thus far, studies focusing on aggressive behavior as a specific aspect of social development are lacking.

### *Inhibitory control, attention, and vocabulary in relation to aggressive behavior*

In addition to negative affect, which is the reactive component of temperament, processes of self-regulation, such as aspects of neuropsychological functioning including inhibitory control and attention, also shape the development of aggressive behavior (Rothbart & Bates, 2006). Inhibitory control is the ability to control behavior by suppressing a dominant response (Garon et al., 2008). Deficits in the ability to control impulses, for example, by waiting for a larger reward or following reverse rules, are related to externalizing behavior problems and specifically aggressive behavior during toddlerhood, preschool and school age (O’Toole et al., 2017; Olson et al., 2017; Schoemaker et al., 2013; van Adrichem et al., 2019).

In addition, orienting to a stimulus and focusing attention are important factors involved in controlling behavior (Rothbart & Posner, 2001). Children who are more able to switch attention are better at modulating their emotional experiences by redirecting attention when stimuli cause negative feelings. Studies examining attentional control showed relations between attention and externalizing behavior problems or aggressive behavior at preschool and school ages (Bellanti & Bierman, 2000; Towe-Goodman et al., 2011). Although support exists for the association between attention and aggressive behavior during toddlerhood (Hill et al., 2006), studies using laboratory tasks instead of questionnaires to assess attention are scarce.



In addition to inhibitory control and attention, another relevant neuropsychological construct in relation to aggression is vocabulary: the capacity to communicate wishes, needs, and desires with parents and peers decreases the level of frustration, which decreases the risk of externalizing behavior problems (Keenan & Shaw, 1997). This hypothesis is reflected in studies showing relations between vocabulary comprehension or production, and externalizing behavior problems or specifically aggressive behavior during toddlerhood, preschool and school age (Chow & Wehby, 2018; Dionne et al., 2003; Girard et al., 2014; Menting et al., 2011).

The aforementioned cognitive abilities might serve as moderators between environmental risk and behavioral outcomes: in case of high early life risk, poor cognitive abilities might increase the risk of externalizing behavior problems, while good cognitive abilities could protect against the development of externalizing behavior problems (Masten, 2001). Whereas a number of studies show support for interactions between inhibitory control and parenting as a potential environmental risk factor in the prediction of externalizing behavior problems (Fatima & Sharif, 2017; van Aken et al., 2007; Yu et al., 2018), only one study used a cumulative risk index. Here, it was found that low inhibitory control and low attention both strengthened the positive relation between number of risk factors and a combined score of internalizing and externalizing problems (Lengua, 2002).

Also, with regard to the relation between the reactive and regulative constructs, an interaction model has been proposed suggesting that the effect of high negative affect on the development of psychopathology increases when children have limited cognitive abilities (Muris & Ollendick, 2005). Studies supporting this moderation model showed increased effects of (aspects of) negative affect on aggression, externalizing behavior problems, or global behavioral functioning, when children had lower inhibitory control, attention, or vocabulary during early childhood (Gartstein et al., 2012; Healey et al., 2010; Jackson, 2017; Lawson & Ruff, 2004; Moran et al., 2013; Suurland et al., 2016). Again, results have not always been consistent, with several studies failing to find interactive effects between aspects of negative affect and cognitive functioning on externalizing behavior problems during toddlerhood or preschool (Belsky et al., 2001; Olson et al., 2005).

### **Current study**

This study examined the main and interactive effects of prenatal cumulative risk, negative affect at 6 and 20 months, and cognitive functions, including inhibitory control, attention, and vocabulary at 30 months, in the prediction of aggressive behavior at 30 months. It was hypothesized that higher prenatal cumulative risk, higher negative affect and lower inhibitory control, lower attention and lower vocabulary would be related to higher levels of aggressive behavior during toddlerhood. In addition, it was hypothesized that two- and three-way interactions between the predictors would show that combinations of high prenatal cumulative risk, high negative affect, and lower cognitive abilities would predict higher levels of aggressive behavior. Based on the evidence for only modest stability of temperamental traits during early childhood (Ferguson, 2010), negative affect was measured at two time points. Because boys and girls were expected to differ in their level of aggressive behavior (Hay et al., 2011), gender was examined as a potential covariate.

## Method

### Participants

This study is part of the Mother-Infant Neurodevelopment Study in Leiden, the Netherlands (MINDS-Leiden; Smaling et al., 2015; Suurland et al., 2017). MINDS-Leiden is a longitudinal study of mother-child dyads focusing on neurobiological and neurocognitive predictors of early behavior problems. The study consists of six data waves from pregnancy until the child is almost 4 years old (third trimester of pregnancy, and 6, 12, 20, 30, and 45–48 months post-partum). Two hundred and ten Dutch-speaking women between 17 and 25 years old ( $M = 22.8$ ,  $SD = 2.4$ ) who were expecting their first child were recruited via hospitals, midwifery clinics, prenatal classes, and pregnancy fairs.

For this study, data of the first (third trimester of pregnancy), second (6 months post-partum), fourth (20 months post-partum) and fifth data waves (30 months post-partum) were used. Sixty mother-child dyads (28.6%) had dropped out at the time of the fifth assessment (at 30 months), due to personal or health problems ( $n = 5$ ), refusal to participate ( $n = 24$ ), inability to contact the mother ( $n = 28$ ), and emigration ( $n = 2$ ). Mothers who left the study tended to have lower family income,  $t(204) = -1.93$ ,  $p = .06$ , had more prenatal risk factors,  $t(75) = 2.68$ ,  $p < .01$ , were more often non-Caucasian,  $\chi^2(1) = 4.26$ ,  $p = .04$ , and more often single,  $\chi^2(1) = 7.27$ ,  $p < .01$ . Dropout was unrelated to maternal age,  $t(208) = 1.47$ ,  $p = .14$ , and work status,  $\chi^2(1) = 1.98$ ,  $p = .16$ .

The final sample consisted of 150 mother-child dyads (75 boys, 50.0%). Five percent of the children were born pre-term (<37 weeks of pregnancy), 20% of the children were born early-term (at 37 or 38 weeks of pregnancy), and 75% of the infants were born full-term ( $\geq 39$  weeks of pregnancy). On average, children were 6.3 months old ( $SD = 0.4$ ) at the second wave, 20.4 months old ( $SD = 0.7$ ) at the fourth wave, and 30.6 months old ( $SD = 1.0$ ) at the fifth wave. The majority of the mothers were Caucasian (88.0%) and had a partner (90.7%). Average family income was 2639 Euros per month ( $SD = 1142$ ).

### Procedures and instruments

The study was approved by the ethics committee of the Department of Education and Child Studies at the Faculty of Social and Behavioral Sciences, Leiden University (ECPW-2011/025), and by the Medical Research Ethics Committee at Leiden University Medical Center (NL39303.058.12). Informed consent was obtained from all participating women.

### Prenatal risk

Mothers were screened for the presence of ten risk factors during the third trimester of pregnancy (0 = absent, 1 = present; Mejdoubi et al., 2011; World Health Organization, 2005): (1) maternal psychiatric disorder, examined using the Dutch version of the Mini-International Neuropsychiatric Interview – plus (Sheehan et al., 1997; Van Vliet et al., 2000), (2) tobacco, (3) alcohol and (4) drug use during pregnancy, (5) teenage pregnancy (<20 years), (6) no secondary education, (7) unemployment, (8) self-reported financial problems, (9) limited social network (<4 persons), examined using the Norbeck Social Support Questionnaire (Norbeck et al., 1981, 1983), and (10) being single (for more detailed information about the risk factors see Smaling et al., 2015). The prenatal cumulative risk score was calculated by summing the risk factors. Prenatal cumulative

risk ranged from 0 to 3 ( $M = 0.63$ ,  $SD = 0.91$ ): 60.7% had no risk factors, 20.7% had one risk factor, 13.3% had two risk factors, and 5.3% had three risk factors. Prevalence of risk factors was 23.3% maternal psychiatric disorder, 12.7% tobacco use, 3.3% alcohol use, and 0% drug use during pregnancy, 6.7% teenage pregnancy, 1.3% no secondary education, 3.3% unemployment, 4.7% financial problems, 4.0% limited social network, and 4.0% being single.

### *Negative affect at 6 months*

The short form of the Infant Behavior Questionnaire-Revised (IBQ-R) was used to examine temperamental negative affect at 6 months (Putnam et al., 2014). Child behavior during the past 2 weeks was scored on a 7-point Likert Scale by the mother using 91 items (1 = never to 7 = always). The total score of the scale Negative affect was used in this study (25 items; possible range of the total score: 25–175; Cronbach's  $\alpha = .67$ ), with higher scores indicating higher levels of negative affect. Data were missing for three children, because mothers did not return the questionnaire.

### *Negative affect at 20 months*

Temperamental negative affect was assessed using the short form of the Early Childhood Behavior Questionnaire at 20 months (ECBQ; Putnam et al., 2006, 2010). The ECBQ consists of 107 items examining child temperament. The frequency of child behavior during the preceding 2 weeks was rated by the mother using a 7-point Likert scale (1 = never to 7 = always). For this study, the total score of the subscale Negative affect was used (48 items; potential range of the total score 48–336; Cronbach's  $\alpha = .79$ ), with higher scores indicating higher levels of negative affect. Data were missing for one child, because the mother did not finish and return the questionnaire.

### *Inhibitory control at 30 months*

Inhibitory control was assessed using the Gift delay task at 30 months (Kochanska et al., 2000). A gift box including a present was placed on a table in front of the child at the end of the assessment. The child was instructed to wait before opening the gift box until the experimenter, who left for 3 min, had returned. Child behavior was coded afterward using videotapes according to a 5-point scale (0 = opens the box and takes the present, 1 = opens the box and takes the present, but puts it back, 2 = opens and peeks inside the box, 3 = touches the box, 4 = does not touch the box). Score 0 and 1 were combined in the analysis, because code 1 was only scored by four children. Data regarding inhibitory control were missing for six children, because child became upset ( $n = 1$ ) or mothers only completed the questionnaires at home at 30 months ( $n = 5$ ).

### *Attention at 30 months*

Attention was examined using an adapted version of the Task orientation paradigm at 30 months (Goldsmith & Rothbart, 1999). While the child was sitting at a table, a music box was placed in front of the child for 2 min. Child behavior was videotaped and the total amount of time the child looked at the music box was coded afterward (potential range 0–120 seconds). Interrater reliability (ICC) was  $\alpha = .99$  (based on 30 videos). Data were missing for 12 children, because mothers only completed the questionnaires at



home at 30 months ( $n = 5$ ), child became upset ( $n = 6$ ), or child behavior was not videotaped because of technical problems ( $n = 1$ ).

### *Vocabulary at 30 months*

Vocabulary was assessed using the Dutch adaptation of the MacArthur-Bates Communicative Development Inventories: Words and Gestures 2a at 30 months (NCIDI-2a short form; Fenson et al., 2000; Zink & Lejaegere, 2003). Mother was instructed to indicate which sounds and words her child understood (vocabulary comprehension) or used (vocabulary production). Because previous research has indicated that language comprehension is more important for behavior problems than language production (Estrem, 2005; Silva et al., 1987), vocabulary comprehension was used in the analyses (potential range: 0–112). No data were missing.

### *Aggressive behavior at 30 months*

Aggressive behavior at 30 months was reported by the mother using the Dutch version of the Child Behavior Checklist for 1.5–5 year old children (CBCL 1½-5; Achenbach & Rescorla, 2000). The CBCL 1½-5 measures emotional and behavior problems during the past 2 months using 99 items. Mothers were asked to rate a child's behavior on a 3-point Likert scale (0 = not true, 1 = somewhat or sometimes true, 2 = very true or often true of the child). The aggressive behavior subscale was used for the analyses (19 items; potential range of the total score 0–38; Cronbach's  $\alpha = .83$ ), with higher scores indicating higher levels of aggressive behavior. Reliability and validity of the CBCL have been supported by several studies (e.g., Achenbach & Rescorla, 2000; Koot et al., 1997).

### *Data analyses*

The analyses were conducted using the Statistical Package for the Social Sciences (SPSS; version 25). First, preliminary analyses, including descriptive statistics and correlations between the study variables, were conducted. Outliers ( $>3$   $SD$  from the mean) were detected for vocabulary at 30 months ( $n = 4$ ) and attention at 30 months ( $n = 3$ ). The outliers were winsorized to the values three standard deviations from the mean. The effect of gender on the study variables was examined using  $t$ -tests.

Next, a series of hierarchical linear regression analyses were conducted to examine the main and interaction effects for prenatal risk, negative affect, and inhibitory control, vocabulary, or attention in the prediction of aggressive behavior at 30 months. The independent variables were  $z$ -standardized prior to calculating the interaction terms to avoid multicollinearity. Model 1 included prenatal risk, Model 2 included negative affect and Model 3 included one of the cognitive constructs (inhibitory control, vocabulary, or attention). We entered the two-way interactions in Model 4, and the three-way interaction in Model 5. Following the recommendations of Aiken and West (1991) and Roisman et al. (2012), significant interactions were plotted at  $\pm 1$   $SD$  from the mean value of the moderator. In addition, interactions were probed using a range from  $-2$   $SD$  to  $+2$   $SD$  from the mean for the independent variable. When these values were out of the range of the observed values, boundaries were adapted to the minimum or maximum value of the variable. Simple slopes analyses using  $t$ -tests were conducted to examine whether the slopes were significantly different from zero. In addition, regions of significance on the

independent variable were examined by using the Johnson-Neyman procedure (Preacher et al., 2006). This procedure examined the range of values of the independent variable for which the association between the moderator and dependent variable was significant. Regions of significance are indicated in gray in the interaction plots. Missing data were handled using pairwise deletion. Significance level was set at  $\alpha < .05$ .

## Results

### Preliminary analyses

Table 1 shows the descriptive statistics of the study variables. First, gender was examined as a potential covariate. A  $t$ -test showed that boys ( $M = 11.92$ ,  $SD = 5.45$ ) and girls ( $M = 11.29$ ,  $SD = 4.95$ ) did not have significantly different levels of aggressive behavior,  $t(148) = 0.74$ ,  $p = .46$ . Therefore, gender was not entered as a covariate in the main analyses.

As shown in Table 2, negative affect at 6 months was significantly correlated to negative affect at 20 months. In addition, higher prenatal risk, higher negative affect at 20 months, and lower inhibitory control at 30 months were significantly correlated with higher levels of aggressive behavior at 30 months. Higher negative affect at 6 months and lower vocabulary were marginally related to more aggressive behavior at 30 months.

### Main analyses

#### Main effects

Results of the hierarchical regression analyses are shown in Table 3. Significant main effects were found for prenatal risk,  $\beta = .19$ -.23,  $p = .01$ -.02: higher risk during pregnancy predicted higher levels of aggressive behavior at 30 months in all models. Significant main effects of negative affect were shown for negative affect at 20 months,  $\beta = .27$ -.30,

**Table 1.** Descriptive statistics of the study variables ( $n = 150$ ).

	<i>n</i>	<i>M</i>	<i>SD</i>	Min	Max
Prenatal risk	150	0.63	0.91	0.00	3.00
Negative affect at 6 months	147	2.58	0.69	1.40	4.73
Negative affect at 20 months	149	2.87	0.47	1.86	4.31
Inhibitory control at 30 months	144	1.51	0.92	0.00	3.00
Vocabulary at 30 months	150	104.88	10.33	71.00	112.00
Attention at 30 months	138	101.18	15.45	49.00	120.00
Aggressive behavior at 30 months	150	11.61	5.20	1.00	23.00

**Table 2.** Correlation analyses between study variables ( $n = 150$ ).

	1.	2.	3.	4.	5.	6.
1. Prenatal risk	–					
2. Negative affect at 6 months	.13	–				
3. Negative affect at 20 months	.28**	.33**	–			
4. Inhibitory control at 30 months	.05	–.05	.03	–		
5. Vocabulary at 30 months	–.22**	.08	.01	–.02	–	
6. Attention at 30 months	–.14	–.03	–.12	.01	.11	–
7. Aggressive behavior at 30 months	.18*	.15 <sup>†</sup>	.30**	–.22**	–.15 <sup>†</sup>	.05

<sup>†</sup> $p < .10$ , \* $p < .05$ , \*\* $p < .01$ .

**Table 3.** Hierarchical regression analyses including prenatal risk, negative affect, and cognitive functions, predicting aggressive behavior at 30 months.

		Negative affect							
		6 months				20 months			
		$R^2$	$\Delta R^2$	$\beta$	$t$	$R^2$	$\Delta R^2$	$\beta$	$t$
Model including Inhibitory control									
1	Prenatal risk	.05	.05*	.22	2.60*	.04	.04*	.19	2.34*
2	Negative affect	.06	.01	.09	1.12	.11	.07**	.29	3.48**
3	Inhibitory control	.10	.04*	-.21	-2.56*	.17	.05**	-.23	-2.98**
4	Prenatal risk $\times$ Negative affect	.12	.02	-.09	-1.10	.21	.04 <sup>†</sup>	.05	0.56
	Prenatal risk $\times$ Inhibitory control			-.13	-1.60			-.19	-2.34*
	Negative affect $\times$ Inhibitory control			.02	0.21			.14	1.72 <sup>†</sup>
5	Prenatal risk $\times$ Neg. affect $\times$ Inh. control	.12	.00	-.02	-0.17	.21	.00	.03	0.31
Model including Vocabulary									
1	Prenatal risk	.04	.04*	.21	2.55*	.04	.04*	.19	2.29*
2	Negative affect	.06	.02	.13	1.57	.10	.07**	.27	3.35**
3	Vocabulary	.07	.01	-.12	-1.38	.12	.02 <sup>†</sup>	-.14	-1.70 <sup>†</sup>
4	Prenatal risk $\times$ Negative affect	.11	.04 <sup>†</sup>	-.09	-1.06	.13	.01	.08	0.93
	Prenatal risk $\times$ Vocabulary			-.02	-0.17			-.07	-0.79
	Negative affect $\times$ Vocabulary			-.19	-2.31*			.03	0.36
5	Prenatal risk $\times$ Neg. affect $\times$ Vocabulary	.12	.01	.08	0.86	.13	.00	.06	0.66
Model including Attention									
1	Prenatal risk	.05	.05**	.23	2.70**	.04	.04*	.20	2.42*
2	Negative affect	.08	.03 <sup>†</sup>	.17	1.97 <sup>†</sup>	.12	.08**	.30	3.50**
3	Attention	.09	.01	.08	0.90	.13	.01	.10	1.24
4	Prenatal risk $\times$ Negative affect	.11	.03	-.02	-0.26	.14	.01	.05	0.62
	Prenatal risk $\times$ Attention			.11	1.19			.07	0.83
	Negative affect $\times$ Attention			-.14	-1.54			.04	0.51
5	Prenatal risk $\times$ Neg. affect $\times$ Attention	.11	.00	.01	0.05	.15	.01	.13	1.37

Neg. affect = Negative affect; Inh. control = Inhibitory control.

<sup>†</sup> $p < .10$ , \*  $p < .05$ , \*\*  $p < .01$ .

$p < .01$ , with higher negative affect at 20 months predicting more aggressive behavior at 30 months, again in all models. Negative affect measured using maternal report at 6 months only showed a marginal effect when attention was included in the model,  $\beta = .17$ ,  $p = .05$ . Regarding the cognitive measures, inhibitory control had significant main effects on aggressive behavior,  $\beta = -.21$ -.23,  $p \leq .01$ , indicating that children with lower inhibitory control showed higher levels of aggressive behavior at 30 months regardless of whether negative affect at 6 or 20 months was included in the analysis. Vocabulary was marginally related to aggressive behavior,  $\beta = -.14$ ,  $p = .09$ , but only in the model including negative affect at 20 months. No main effects for attention were observed.

### *Prenatal risk $\times$ negative affect interactions*

No significant two-way interaction effects between prenatal risk and negative affect at 6 or 20 months on aggression were found.

### *Prenatal risk $\times$ cognition interactions*

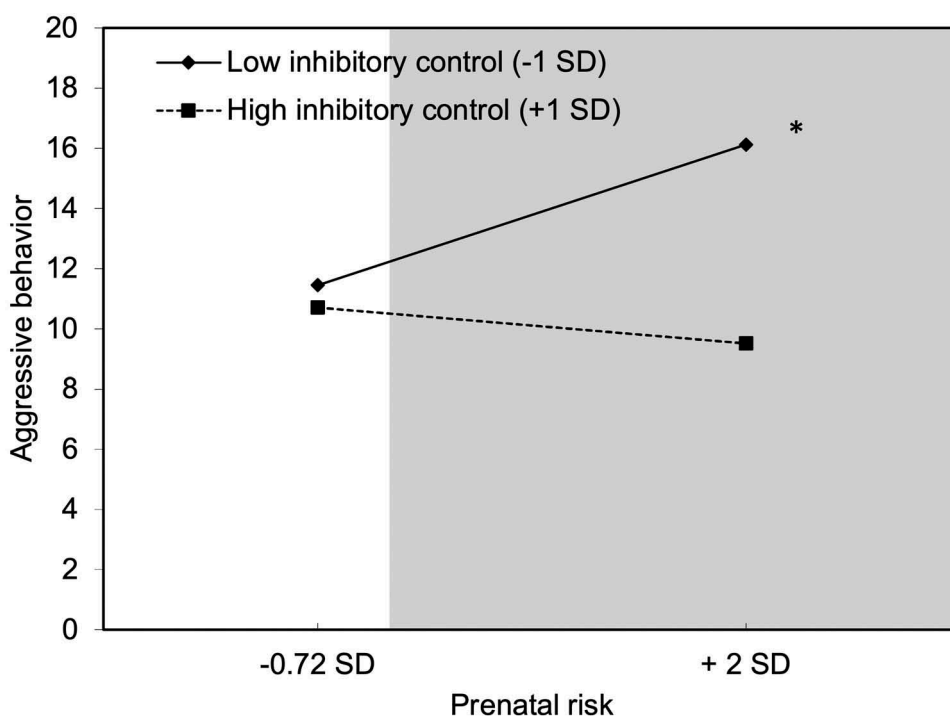
A significant two-way interaction between prenatal risk and inhibitory control was found predicting aggressive behavior,  $\beta = -.19$ ,  $p = .02$ , although it should be noted that this effect was only found when negative affect at 20 months was included in the model. The interaction is plotted in [Figure 1](#): higher prenatal risk was related to higher levels of aggressive behavior in children with low inhibitory control ( $-1$  SD),  $B = 1.72$ ,  $t = 2.61$ ,  $p = .01$ , while children with high inhibitory control ( $+1$  SD) showed low levels of

aggressive behavior, independently of prenatal risk,  $B = -0.44$ ,  $t = -0.44$ ,  $p = .48$ . The regions of significance analysis indicated that the association between inhibitory control and aggression was significant for prenatal risk values above  $-0.31$  SD from the mean (indicated by the gray area in Figure 1). No significant interaction effects between prenatal risk and vocabulary or attention were found.

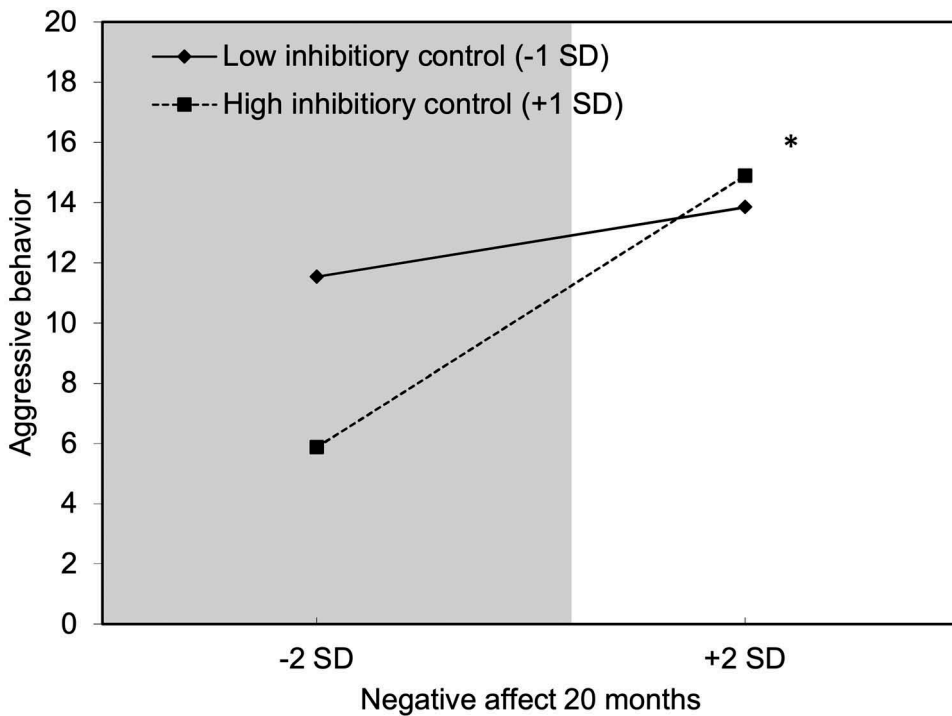
### Negative affect $\times$ cognition interactions

The interaction between negative affect at 20 months and inhibitory control on aggressive behavior was marginally significant,  $\beta = .14$ ,  $p = .09$ . As shown in Figure 2, children with low inhibitory control ( $-1$  SD) had higher levels of aggressive behavior, independent of negative affect,  $B = 0.58$ ,  $t = 0.89$ ,  $p = .38$ , while there was a positive relation between negative affect and aggressive behavior for children with higher levels of inhibitory control ( $+1$  SD),  $B = 2.26$ ,  $t = 3.63$ ,  $p < .01$ . The regions of significance analysis indicated that the association between inhibitory control and aggression was significant for negative affect below  $0.33$  SD from the mean (indicated by the gray region in Figure 2).

In addition, a significant interaction was found for negative affect at 6 months and vocabulary at 30 months,  $\beta = -.19$ ,  $p = .02$ . As shown in Figure 3, no relation between negative affect and aggressive behavior was found for children with high vocabulary ( $+0.7$



**Figure 1.** Interaction effect between prenatal risk and inhibitory control on aggressive behavior. Because the value associated with  $-2$  SD from the mean of prenatal risk was out of range of the observed values, the plotted minimum was adapted to  $-0.72$  SD from the mean. The gray-shaded area (prenatal risk  $> -0.31$  SD) indicates the region of significance: the area of prenatal risk for which the inhibitory control–aggression relation is significant.



**Figure 2.** Interaction effect between negative affect and inhibitory control on aggressive behavior. The gray-shaded area (negative affect  $< 0.33$  SD) indicates the region of significance: the area of negative affect for which the inhibitory control–aggression relation is significant.

SD, because  $+1$  SD was out of the observed range),  $B = 0.16$ ,  $t = 0.32$ ,  $p = .75$ . For children with low levels of vocabulary ( $-1$  SD), higher negative affect was related to more aggressive behavior,  $B = 1.67$ ,  $t = 2.98$ ,  $p < .01$ . The regions of significance analysis indicated that the association between vocabulary and aggression was significant for negative affect above  $0.48$  SD from the mean (indicated by the gray area in Figure 3). Other two-way interactions between negative affect and cognition were not significant.

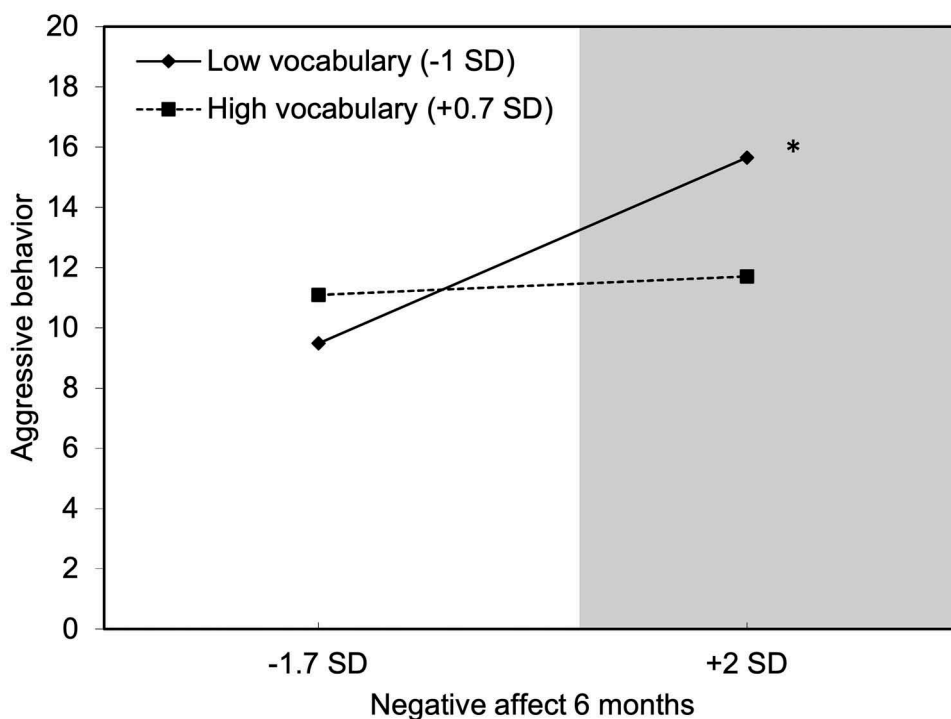
#### *Prenatal risk x negative affect x cognition interactions*

No significant three-way interactions between prenatal risk, negative affect, and cognition were found.

## Discussion

This study examined the main and interactive effects of prenatal risk, negative affect, and cognition on aggressive behavior during toddlerhood. Higher prenatal risk and more negative affect at 20 months, and to a lesser extent also at 6 months, were related to higher levels of aggressive behavior at 30 months. Regarding the cognitive constructs, children with lower levels of inhibitory control and, to a lesser extent, vocabulary showed more aggression, whereas attention did not predict aggressive behavior. Interaction effects in





**Figure 3.** Interaction effect between negative affect and vocabulary on aggressive behavior. Because the value associated with  $-2$  SD from the mean of negative affect at 6 months was out of range of the observed values, the plotted minimum was adapted to  $-1.7$  SD from the mean. Also, the value associated with  $+1$  SD from the mean of vocabulary was out of the range of the observed values. Therefore, high vocabulary was plotted at  $+0.7$  SD from the mean. The gray-shaded area (negative affect  $>0.48$  SD) indicates the region of significance: the area of negative affect for which the vocabulary–aggression relation is significant.

the prediction of aggression were found between prenatal risk and inhibitory control and between negative affect at 6 months and vocabulary. Furthermore, the interaction between negative affect at 20 months and inhibitory control was marginally significant.

### ***Prenatal risk and negative affect in relation to aggression***

This study showed that higher prenatal risk was related to higher levels of aggressive behavior at 30 months. This finding is consistent with previous studies demonstrating a positive relation between the presence of specific risk factors or the number of risk factors and the level of child externalizing behavior problems (Carneiro et al., 2016; LaPrairie et al., 2011; Latimer et al., 2012). Due to children's psychophysiological adaptation to repeated or prolonged exposure to prenatal risk, lasting alterations in regulatory systems may arise, such as changes in hormonal systems and brain regions involved in emotional processing (Ganzel et al., 2010; Juster et al., 2011; McEwen, 2000; Sterling, 2012), which, in turn, may lead to behavior problems (Juster et al., 2011). In addition, part of the association may be explained by the heritability of psychopathology (Lahey et al., 2011).

As hypothesized, results also showed that higher negative affect at 20 months was related to more aggression at 30 months. Previous research during early childhood showed that negative affect and specific aspects of temperamental reactivity were related to externalizing behavior problems (e.g., DeLisi & Vaughn, 2014; De Pauw & Mervielde, 2010; Sanson et al., 2004). For negative affect at 6 months, this study only indicated one marginally significant association (and two non-significant associations) with aggressive behavior in the hierarchical regression analyses. These results, therefore, emphasize the importance of including temperament at different ages. Although it was traditionally assumed that temperamental traits were affected mainly by genetic aspects, the only modest-to-moderate stability of temperament during early childhood (which was confirmed in the present study) emphasizes the potential environmental influences on temperament (Carranza et al., 2013; Emde et al., 2001; Ferguson, 2010; Nigg, 2006). Temperament may show development with age due to, for example, changes in contexts or changes in normative behavior during developmental challenges (Nigg, 2006), which could explain the contradictory findings.

The results of this study did not support the hypothesized interaction effect between prenatal risk and negative affect. According to the diathesis-stress model, children with high negative affect were expected to be more likely to show aggressive behavior in case of high prenatal risk, whereas low negative affect was expected to serve as a protective factor (Monroe & Simons, 1991; Nigg, 2006). In line with our results, there are several other studies using a cumulative risk index that did not find this interaction effect during early childhood either (Lengua, 2002; Northerner et al., 2016). Support for the diathesis-stress model including negative affect was found mainly when parenting behavior instead of prenatal risk was included as an environmental risk factor (Bradley & Corwyn, 2008; Slagt et al., 2016), or studies focusing on broader aspects of social behavior (Chang et al., 2012). Our results suggest that high prenatal risk is associated with more aggressive behavior, independently of child's temperamental reactivity, although a mediation effect through negative affect cannot be ruled out, as prenatal risk and negative affect (at 20 months) were significantly related (and both were related to aggression at 30 months).

### *Prenatal risk and cognition in relation to aggression*

In addition to negative affect, which is the reactive component of temperament, we also hypothesized that deficits in self-regulation processes, defined as aspects of neuropsychological functioning, would be related to more aggression (Rothbart & Bates, 2006). It was found that lower inhibitory control predicted higher levels of aggressive behavior during toddlerhood. This finding is in line with previous research in preschool and school ages (O'Toole et al., 2017; Raaijmakers et al., 2008; Schoemaker et al., 2013) by indicating that children with problems to control impulses and to inhibit dominant responses show more aggression during toddlerhood. The type of inhibitory control elicited by the delay task may be classified as "hot" inhibitory control (Garon et al., 2008), which involves motivational and emotional components. Although we did not have a task available measuring "cool," or decontextualized inhibitory control at this age, results of the present study specifically indicate the importance of "hot" inhibitory control for the development of externalizing behavior problems (Huijbregts, Warren, et al., 2008; Kim et al., 2013). The fact that attention and vocabulary did not, or to lesser

extent predict aggressive behavior during toddlerhood, further emphasizes the importance of relatively poor inhibitory control as a specific cognitive risk factor for aggressive behavior.

In addition, it was found that relatively good inhibitory control served as a protective factor in case of high prenatal risk: while higher prenatal risk was related to higher levels of aggressive behavior for children with low inhibitory control, no risk–aggression relation was found for children with high (or relatively good) inhibitory control. This interaction shows that children who experienced high prenatal risk show high levels of aggression, but only when they are unable to regulate impulses and behavior. These findings corroborate the results of Lengua (2002), who described a comparable risk–inhibitory control interaction focusing on a combined outcome of internalizing and externalizing behavior problems during school age.

### *Negative affect and cognition in relation to aggression*

With regard to the interaction between the reactive and regulative constructs, it was hypothesized that higher negative affect would be related to higher levels of aggressive behavior, but only in children with relatively poor cognitive abilities (Gartstein et al., 2012; Muris & Ollendick, 2005). Surprisingly, the marginally significant interaction effect including inhibitory control indicated that there was a positive relation between negative affect at 20 months and aggressive behavior, but only for children with relatively good inhibitory control. Children low in inhibitory control scored relatively high on aggressive behavior, regardless of the level of negative affect. This finding indicates that relatively good inhibitory control did not have a protective role in case of high negative affect, as hypothesized, but that relatively poor inhibitory control served as a risk factor. The direction of the interaction was not entirely similar to the results of earlier research (Moran et al., 2013; Suurland et al., 2016), which suggested that behavior problems are more pronounced in children showing high negative affect in combination with low inhibitory control.

In addition, vocabulary moderated the effect of negative affect at 6 months on aggressive behavior: high negative affect was related to higher levels of aggression in children with relatively limited vocabulary, while there was no relation for children with high vocabulary. This finding is consistent with those reported in previous research, showing that externalizing behavior problems are most pronounced when children have high negative affect combined with low vocabulary (Jackson, 2017).

### *Attention in relation to aggressive behavior*

Although previous studies found main effects of attention on behavior problems (Bellanti & Bierman, 2000), or interactions of attention with risk (Lengua, 2002) or negative affect (Lawson & Ruff, 2004), our analyses did not confirm these results. The absence of effects for attention may be due to the outcome measures chosen: it has been suggested that attention is more prominently involved in the development of internalizing behavior problems compared to externalizing behavior problems (Gartstein et al., 2012; Muris & Ollendick, 2005). Also, several studies reporting the effects of attention used broad scales of problem behavior, including internalizing behavior problems, as outcome measure

(Lawson & Ruff, 2004; Lengua, 2002). In addition, our measure of attention reflected a combination of sustained and focused attention, while other components, such as attention shifting, were not taken into account (Mirsky et al., 1991). Future studies are encouraged to examine different aspects of attention in relation to internalizing and externalizing behavior problems.

### *Strengths and limitations*

A clear strength of this study is combining several well-established risk factors, i.e., prenatal risk, negative affect, and cognition, in the prediction of aggressive behavior during the first years of life. Whereas most studies focused on preschool age, this study provided evidence for (interactive) influences, already during toddlerhood. In addition, we used a longitudinal design focusing on different time points in children's development, including two measurements of temperamental negative affect. Another strength of this study is the use of performance-based tasks (except for vocabulary) to examine the role of specific aspects of cognition in aggressive behavior. The results of this study should, however, also be interpreted considering several limitations. First, the prenatal risk score ranged only from 0 to 3. Results regarding prenatal risk should be interpreted with caution because of this ordinal scale with a relatively narrow range. Moreover, the results of these analyses may not easily translate to mother-child dyads experiencing very high levels of risk. In addition, the parent report measures of negative affect and aggressive behavior show some overlap in the item-content, which might raise the concern of an inflated relation between these two constructs. However, previous research showed that the associations between temperament and behavior problems were not affected by measurement confounding, because removing the overlapping items did not change the results (Lemery et al., 2002; Martel & Nigg, 2006; Oldehinkel et al., 2004). However, future studies should examine the main and interactive effects using behavioral observations of negative affect and aggressive behavior. In addition, our study focused on the broad construct of negative affect, which includes, for example, sadness, fear, and frustration. Because these specific aspects may show differential effects in relation to behavior problems (Gartstein et al., 2012; Moran et al., 2013), future studies should differentiate between the specific aspects of negative affect when examining interactions with prenatal risk and cognition. In addition to prenatal risk, several studies have identified numerous (postnatal) risk factors, such as poor parenting behavior and paternal psychiatric disorder, with an influence on the development of aggressive behavior during early childhood (Dave et al., 2008; McKee et al., 2008; Ramchandani et al., 2013). In order to be able to examine all potential risk factors for the development of early aggressive behavior simultaneously, very large sample sizes are required. Still, it would be of interest for future studies into prenatal risk, cognitive functioning, and aggressive behavior to include factors such as paternal influences and parenting behavior as well.

### *Implications*

This study showed both main and interactive effects for high prenatal risk, high negative affect, and low cognition in the prediction of aggressive behavior during toddlerhood. Results suggest that expecting woman living in a high-risk environment should be identified during pregnancy, at which time point they should also be considered for

preventive interventions regarding offspring aggression. In line with this suggestion, it has been reported that better child outcomes are achieved when interventions are started as early as possible, preferably during pregnancy (Peacock et al., 2013; Rothbart, 2007; Tremblay, 2010). In addition, this study showed that relatively poor inhibitory control (in motivational or emotional contexts) and vocabulary are related to aggressive behavior during toddlerhood, especially in combination with high prenatal risk or high negative affect. Research showed promising results with respect to interventions aimed at enhancing cognitive abilities, such as inhibitory control (or executive functioning in a broader sense) and vocabulary (Diamond & Lee, 2011; Dowsett & Livesey, 2000; Marulis & Neuman, 2010), in order to prevent or reduce externalizing behavior problems during preschool (Curtis et al., 2019; Volckaert & Noel, 2015). Further studies are needed to examine the effects of training of these cognitive constructs on aggressive behavior during toddlerhood.

### Disclosure statement

The authors report no conflict of interest.

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